Home Work 3
Due on November 17

Problem 1 (30 points)

a) *(from Liou, 3.7) The number of molecules per cubic centimeter of air at sea level in standard atmsopheric conditions is about 2.55x 10^{19} cm^{-3}. Calculate the scattering cross-section of molecules at the 0.3, 0.5 and 0.7 μm.*

b) *(from Liou, 3.8). The number density profile as a function of height is given by the following table:*

Height (km)	*0*	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*
N(x10^{18} cm^{-3})	*25.5*	*20.9*	*17.0*	*13.7*	*10.9*	*8.60*	*6.49*	*4.74*	*3.46*

Calculate the optical depth of a clear atmosphere at the wavelengths for part a).

Problem 2 (30 points)

a) *For large size parameters, say $x > 50$, the extinction efficiency asymptotes to Q_{ext}=2. Relate the volume extinction coefficient, β_{ext}, of a particle size distribution to the liquid water content (LWC) and the effective radius.*
b) *Use the above relation to determine the extinction of a lognormal droplet distribution with N=10 cm^{-3}, r_0=2μm, and σ=0.4.*

Problem 3 (20 points)

The parameters needed for a two-stream radiative transfer flux calculation in a scattering atmosphere are the optical depth τ, single scattering albedo ω, and the asymmetry parameter g. Consider the cloud and haze layer from about 50 to 65 km in the Venusian atmosphere. The cloud and haze droplets are sulfuric acid. At a wavelength of 500 nm the index of refraction is m=1.45. Assume that the optical depth of the cloud droplets is 25 and of the haze is 3. The asymmetry parameter of the cloud droplets is 0.78 and of the haze is 0.70.

a) *Write down an expression for the total optical properties of the layer (τ, ω, and g) from these optical properties for the cloud and haze scattering.*
b) *Compute the total τ, ω, and g for the layer.*

Problem 4 (20 points).

a) *Calculate the delta-isotropic scaled optical properties (β, ω, g) for λ=11 μm cloud case, if Mie results give extinction β=38.87 km^{-1}, single scattering albedo ω=0.4748, and asymmetry parameter g=0.924. Use delta-isotropic scaling approximation.*
b) *Given the results in part a, what two approximate solutions to the thermally emitting and scattering radiative transfer equation would be both accurate and computationally efficient? Explain why. Hint: the second approximation is more accurate than first.*

Problem 5 (40 points)

a) *Show that for an optically thin atmosphere and a very dark surface, the combined atmosphere-surface reflectivity is simply the sum of the reflectivity of the atmosphere and surface.*

b) *In visible and near IR remote sensing the radiance is often normalized by the incident solar flux to give the reflectance which is defined by* $R=\pi I/(\mu_0 S_0)$*. Calculate this reflectance in the direction* $\theta=30°$, $\varphi=140°$ *from an atmosphere containing only a 1.0 km layer of the mineral aerosol that is characterized by a single scattering albedo,* $\omega=0.888$*, asymmetry parameter* $g=0.6815$*, phase function* $P_{Mie}(\theta)=0.3787$*, and extinction* $\beta=0.321\ km^{-1}$*. The surface is Lambertian with an albedo of 0.04. The direction to the sun is* $\theta_0=30°$, $\varphi_0=180°$*. Calculate the total reflectance for two cases: i) the actual aerosol Mie phase function, and ii) the Henyey-Greenstein phase function for the same asymmetry parameter.*